Amorphous Silicon Solar Cell Research at BP Solar

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ABSTRACT

In the past year, the amorphous silicon (a-Si) research program at BP Solar has been directed toward improving the performance of both single-junction and tandem modules, and also increasing the throughput of the BP Solar TF1 manufacturing facility. The performance of a-Si solar cells has been improved by several percent by an optimization of the back zinc oxide contact layer. In addition, a new technique has been developed that provides a low resistance contact when an a-Si p-layer is deposited on a zinc oxide substrate. New plasma diagnostic tools were also developed to help characterize and control the plasma deposition process. This ongoing research and development effort has led to the successful ramp-up of the TF1 manufacturing facility in Toano, Virginia, which is now operating at run rate of about 8 MW per year with electrical yields of 8.6 ft^2 tandem modules running above 90%.

1. Introduction

BP Solar is continuing to improve the performance of a-Si solar cells and modules while simultaneously ramping up the production of a-Si/a-SiGe tandem modules at its TF1 plant in Toano, VA. In this paper, we present some recent results on increasing the performance of both single-junction and tandem a-Si based solar cells by improving the front and rear contacts of the cells. We have also developed an in-situ plasma diagnostic system that utilizes an array of fiber optic probes to measure the spatial uniformity of the plasma emission during deposition. The ongoing R&D program at BP Solar has led to a ramp-up of the a-Si PV module manufacturing plant in Toano, Virginia to a run-rate of 8 MW/yr.

2. Increasing the Deposition Rate of a-Si:H

The throughput of the BP Solar TF1 a-Si plant is mainly limited by the rate at which the a-Si alloy films can be deposited. As shown by the data in Fig. 1, we have been able to increase the deposition rate of the a-Si:H i-layer to 10 Å/s without suffering a serious decrease in stabilized conversion efficiency. The devices in these experiments were all fabricated in a single-junction p-i-n configuration on commercial tin oxide (SnO_2) coated glass. The cells were subjected to ~ 600 hours of light soaking at ~ 0.8 suns at ~ 40°C.

3. Improving the Front Contact

Until recently, our investigation of zinc oxide (ZnO) as a potential front contact layer for a-Si solar cells has had limited success. We have typically observed enhancements of 10-15% in the photocurrents of a-Si cells made on ZnO/

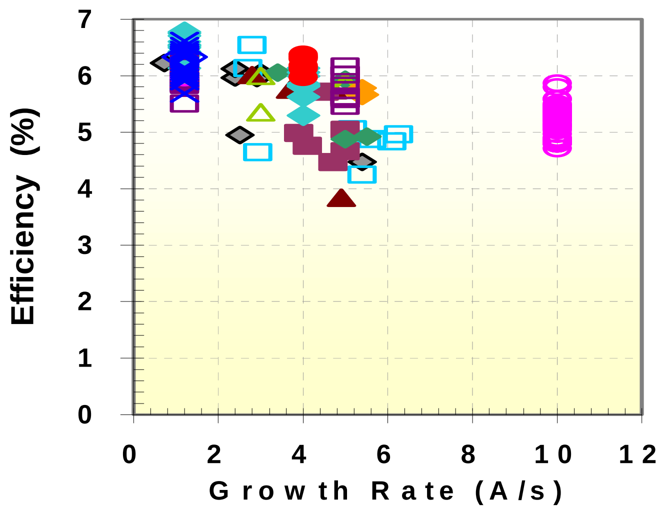

Fig. 1. The stabilized conversion efficiency of a-Si single-junction cells as a function of the growth rate of the i-layer.

glass substrates as compared to cells made on SnO_2 coated glass substrates. However, both the fill factor and open-circuit voltages are usually lower for cells grown on ZnO [1]. We have recently developed a new process that allows us to make good electrical contacts to a ZnO layer while maintaining high photocurrents.

The data in Fig. 2 show that the new process results in single-junction devices on ZnO with fill factors that are slightly better than those obtained on SnO_2. In fact, the fill factors are ~9% better than those for devices grown on ZnO using our standard process. The ZnO in these experiments was grown at Harvard University using APCVD and was lightly textured (~3% haze). The average conversion efficiency for devices made with the new process was ~9% higher than that obtained for control devices on commercial SnO_2/glass substrates.

4. Improving the ZnO Rear Contact

Both single-junction and tandem cells made at BP Solar utilize a ZnO/Al rear contact where the ZnO is deposited by either magnetron sputtering or by low-pressure chemical vapor deposition (LPCVD). As shown in Fig. 3, the photocurrent of single-junction cells has been increased by 7-8% by optimizing either the oxygen or the water vapor content of the sputtering atmosphere during the deposition of the back ZnO contact.

5. New Plasma Diagnostic Tool

We have found that a-Si PV module performance depends critically on the reactor geometry especially for large-area deposition systems where variations in electrode

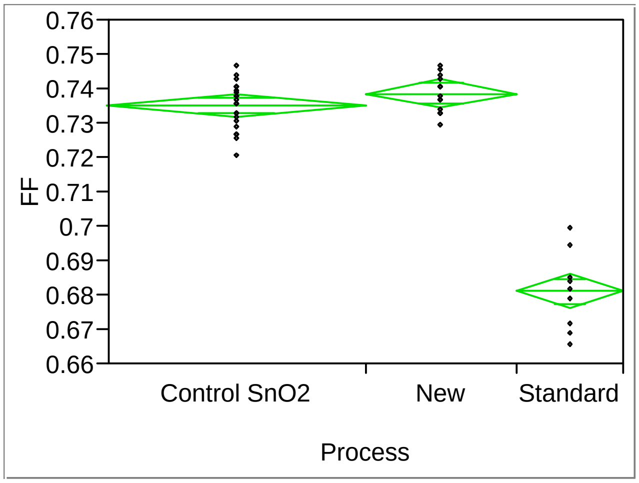

Fig. 2. The fill factor for a-Si single-junction cells made with the standard process on SnO_2 and ZnO substrates and with a new process on ZnO substrates.

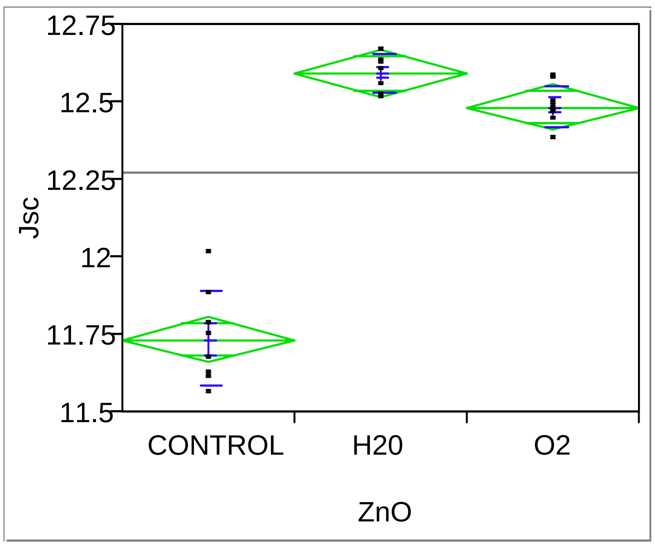

Fig. 3. The short-circuit current density for a-Si single-junction cells made with varying amounts oxygen or water vapor in the sputtering atmosphere for the rear ZnO layer.

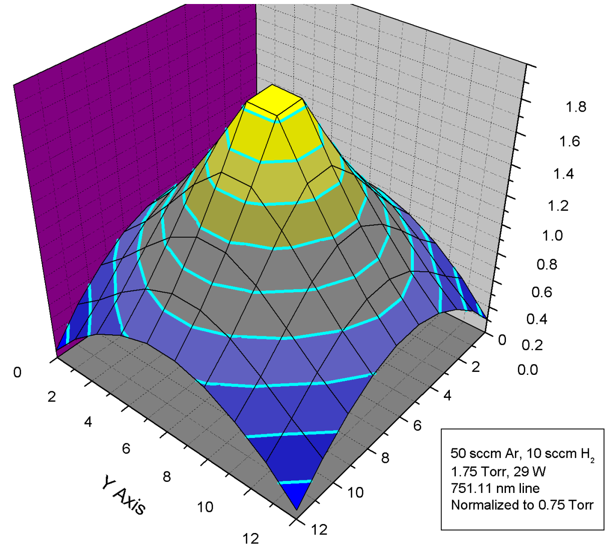

Fig. 4. Contour plot of the 751.11 nm Ar emission line in a 5:1 Ar:H_2 discharge at a pressure of 1.75 Torr.

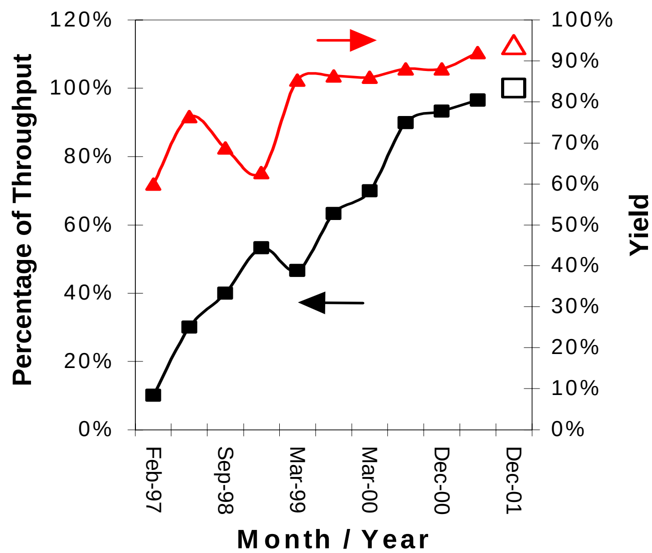

Fig. 5. Throughput and electrical yield as a function of time for the BP Solar TF1 plant in Virginia.

spacing can lead to wide variations in stabilized performance [2]. In order to monitor and control variations in reactor geometry, we have developed a characterization tool that utilizes an array of fiber optic probes to detect the spatial variation of the optical emission over the deposition zone. In Fig. 4 we show a contour plot of the emission at 751.11 nm in an Ar-H_2 discharge at 1.75 Torr. As the discharge pressure is lowered, the plasma emission contour changes from convex to uniform and finally becomes concave at low pressures. This tool allows us to determine and maintain the plasma deposition conditions required to obtain uniform a-Si alloy layers.

6. Improvements in the Operation of the TF1 Plant

As shown by the throughput and plate yield data in Fig. 5, good progress has been made in ramping up production at the TF1 plant in Virginia, which manufactures 8.6 ft^2 a-Si/a-SiGe PV modules. The drop in yields experienced in mid-1998 necessitated a reduction in throughput in order to solve several processing problems. The plant has recently been running with electrical plate yields > 90% at a run rate of about 8 MW per year.

ACKNOWLEDGEMENTS

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